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The bichrome test: Comparing the use of lights as stimulus targets to the use of shadows

Michael H. Cho
Pacific University

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Abstract

The standard bichrome·(duochrome) test consists of using black letters with a red and 9reen background. The patient is asked. to distinguish the less blurry or more clear letters and therefore uses central fixation to distinguish black letters and an off foveal area to detect red and green. This may contribute to insensitivity to the test and inaccurate spherical findings. The traditional method was compared with a second method in which the letters are red and green and the background is black. The latter was found to be a viable alternative that is more sensitive than the standard test.

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The Bichrome Test: Comparing the use of lights as stimulus targets to the use of shadows

Michael H. Cho
Advisor: Niles Roth, O.D., Ph.D.
Pacific University College of Optometry

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Michael H. Cho
Advisor: Niles Roth, O.D., Ph.D.
Niles Roth

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ABSTRACT

The standard bichrome (duochrome) test consists of using black letters with a red and green background. The patient is asked to distinguish the less blurry or more clear letters and therefore uses central fixation to distinguish black letters and an off foveal area to detect red and green. This may contribute to insensitivity to the test and inaccurate spherical findings.

The traditional method was compared with a second method in which the letters are red and green and the background is black. The latter was found to be a viable alternative that is more sensitive than the standard test.

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INTRODUCTION

The bichrome test is a subjective refraction procedure used to determine spherical correction. It is based on axial chromatic aberration of the human eye in which refrative power increases with decreasing wavelength.

In 1933, Pech predicted that since the eye is most sensitive to yellow light, the average person, in the interest of maximum acuity, places the smallest yellow blur circle upon the retina (1).

Although, the bichrome test has proven to be valuable in subjective refraction, clinically it has its drawbacks. The success of the test depends upon the patient's ability to discriminate equal brightness of red and green lights. If the sensitivity to either red or green is changed then the patient's response will also be changed (2).

Most conventional projection charts provide test details as shadows with bright backgrounds thereby emphasizing the "ground" and not the "figure." When red and green backgrounds are used, the patient uses color boundaries and not letter details as a basis for judgement (3). A patient asked to view the black letters uses central fixation (cone vision) to view the shadows and rod vision to view the background. This may lead to a decrease in sensitivity to the test. The use of luminous details seen against a dark background may serve as a more critical test procedure.

METHODS

SUBJECTS

Nineteen subjects ranging from 18-38 years of age were randomly drawn from the Pacific University patient population. They were selected regardless of their refractive errors;however, subjects could not be tested with tinted contact lenses or if they had color vision deficiencies.

METHOD AND MATERIALS

Two-inch square 35mm projector slides of 20/40 letters were used. The slides were made by using a positive and a negative with red and green acetates. The negative slide projects red and green letters with a black background and the positive slide projects black letters or shadows with a red and green background. A Kodak Ektagraphic slide projector model AF-1 with a 5-inch f:3.5 Ektanar lens was used to project both slides. An American Optical phoropter and projector were used for refraction.

Aided monocular visual acuities were taken to ensure that the patient's visual acuity was 20/40 or better. The sequence of testing was as follows:

1. One of the bichrome tests.
2. Monocular visual acuities.
3. 20/40 Jackson Cross Cylinder Test.
4. Monocular subjective to best visual acuity test.
5. Monocular visual acuities.

The sequence was repeated with the other red-green test slide starting with the habitual correction. To balance out practice effects, the sequence of using red-green test slides was reversed on every patient.

RESULTS

TABLE I

BVA a	SLIDE 1 BICROME b	DIFF. b-a	BVA d	SLIDE 2 BICHROME e	DIFF. e-d
+0.50	-0.50	-1.00	+0.62	-0.37	-0.99
-1.50	-2.00	-0.50	-1.37	-2.00	-0.63
-0.37	-0.87	-0.50	-0.50	-0.87	-0.37
plano	-1.06	-1.06	+0.12	-0.12	-0.24
-0.37	-1.15	-0.78	-0.62	-0.66	-0.04
+0.25	-0.06	-0.31	+0.50	-0.78	-1.28
-0.12	-1.75	-1.63	-0.12	-0.97	-0.85
+0.62	plano	-0.62	+0.50	+0.41	-0.09
-2.75	-3.03	-0.28	-2.88	-2.94	-0.06
+0.25	-0.25	-0.50	+0.37	plano	-0.37
-1.62	-2.00	-0.38	-1.62	-1.69	-0.07
plano	-0.25	-0.25	-0.12	-0.28	-0.16
plano	+0.21	+0.21	-0.12	-0.31	-0.19
-4.25	-4.50	-0.25	-4.12	-4.25	-0.13
+0.50	-0.42	-0.92	+0.62	-0.16	-0.78
+0.12	-0.59	-0.71	-0.12	-0.44	-0.32
-1.00	-1.12	-0.12	-1.00	-1.00	plano
+0.50	-0.78	-1.28	+0.25	-0.30	-0.55
-1.50	-3.00	-1.50	-1.62	-1.87	-0.25

SLIDE 1: N=19 M=0.651579 S=0.482934 V=0.233225 SS=4.19805 T-Value=5.88106
SLIDE 2: N=19 M=0.387894 S=0.363862 V=0.132395 SS=2.38311 T-Value=4.64680
DIFFERENCES: N=19 M=0.251052 S=0.482768 V=0.233065 SS=4.19518 T-Value=2.26674

The spheres to best visual acuity (BVA) of both eyes of each subject were averaged and compared to the average of each bichrome test. The difference between the spherical values of the BVA and the bichrome sphere values were analyzed using a T-test (4).

It was found that there was a significant difference between the bichrome tests at the .05 level (observed T=2.26674) Table I. By calculating the mean of the differences between each bichrome test and its BVA, the results show that Slide 1 results, the new test, had a higher mean value (M=0.651579) than did Slide 2 results (M=0.387894). Moreover, Slide 1 results showed a larger variance (0.233225) and T-value (5.88106) when compared to Slide 2 (V=0.132395, T-value=4.64680), indicating greater scatter in the results and a more highly significant difference between Slide 1 results and the reference (BVA) values.

TABLE II

	GREEN LETTERS a (cd/m²)	RED LETTERS b (cd/m²)	GREEN/RED a/b
O	4.6	1.5	3.1
F	6.1	2.4	2.5
L	5.0	1.4	3.6
C	7.2	2.0	3.6
T	6.5	2.9	2.2
B	4.2	2.5	1.7
			Ave. 2.8

TABLE III

	GREEN BACKGROUND a (cd/m²)	RED BACKGROUND b (cd/m²)	GREEN/RED a/b
SUPERIOR	20.5	1.7	12.1
INFERIOR	21.2	2.2	9.6
SUPERIOR	34.8	2.0	17.4
INFERIOR	34.2	2.1	16.3
			Ave. 13.85

DISCUSSION

Comparing the mean differences between each bichrome test and its respective BVA reference, the test slide using red and green letters on a black background (Slide 1) shows a higher value than the test slide using black letters on a red and green background (Slide 2). This indicates a requirement for more minus lens power to balance clarity between the red and green letters with Slide 1. A statistical comparison between each bichrome test and its respective BVA shows a significant T-value at the .05 level with both slides. However, Slide 1 shows a much higher level of significance (5.88106 vs. 4.64680) than Slide 2.

When the slides were designed it was assumed that the luminance difference would have a constant effect in both tests since the same acetates were used in fabricating both test slides. However, this was not the case. Using a UDT model 11A Photometer, the luminance ratio of green to red was measured for each slide. Tables II and III show that Slide 2 had a higher luminance ratio than did Slide 1. Contrary to what was expected, subjects noted greater luminance differences between green and red in Slide 1 and not as much in Slide 2. During testing, subjects reported that the green letters in Slide 1 were brighter than the red letters and created a "dispersion effect" around the edges of the letters. One subject reported that the "dispersion effect" resulted in the initial impression that the green letters were more blurry than they really were upon closer examination.

Apparently, the luminance difference played an important role in the experiment. Due to an excess of transmittance by the green acetate, more light gave the appearance of glare or ghost images which allowed more minus lens power to be added for red-green balance, particularly with Slide 1.

Interestingly, Slide 2 results did not appear to have been affected as much by the difference in transmittance of the acetates. This appears consistent with what Wesley and Jessen described in contact lens wearers (3). They found that some contact lens wearers complain of ghost images emanating from the bright surrounds despite their ability to read black letters as small as 20/15. This complaint was attributed to improper centering of the contact lens. This is similar to the present findings that the greater visual impact occurred when the figure was brighter than the ground as in Slide 1. Most subjects did notice that the green side of Slide 2 was brighter, but it did not affect their judgement in distinguishing when the letters on each side of the slide were equal in appearance.

It is believed by this author that the increase in sensitivity to the difference in luminance with Slide 1 may be attributed to the letters being a foveal light stimulus to the eye as well as an acuity target. With Slide 2 the black letters serve as an acuity target, but the background serves as the light stimulus to the eye.

The fact that the sphere values of Slide 2 were closer to the BVA reference values than was the case with Slide 1 is not significant in this experiment because the increase in sensitivity to Slide 1 altered its findings. Rather, one should note the difference in sensitivity and use it to advantage in clinical procedures.

In conclusion, using red and green letters on black background is an acceptable alternative to the bichrome test, allowing the subject to exercise finer discrimination.

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